

CHAPTER 850 PHYSICAL STANDARDS

Topic 851 - General

Index 851.1 - Introduction

This section deals with the selection of drainage facility material size and type(s).

851.2 Selection of Material and Type

The choice of drainage facility material size and type is based on the following factors:

- (1) *Physical and Structural Factors.* Of the many physical and structural considerations, some of the most important are:
 - (a) Durability.
 - (b) Headroom.
 - (c) Earth Loads.
 - (d) Bedding Conditions.
 - (e) Conduit Rigidity.
 - (f) Impact.
 - (g) Watertightness.
- (2) *Hydraulic Factors.* Hydraulic considerations involve:
 - (a) Design Discharge.
 - (b) Shape, slope and cross sectional area of channel.
 - (c) Velocity of approach.
 - (d) Outlet velocity.
 - (e) Total available head.
 - (f) Bedload.
 - (g) Inlet and outlet conditions.
 - (h) Slope.
 - (i) Smoothness of conduit.
 - (j) Length.

Suggested values for Manning's Roughness coefficient (n) for design purposes are given in Table 851.2 for each type of conduit. See Index 864.3 for use of Manning's formula.

- (3) *Maintenance and Construction Factors.*

- (a) Local experience.
- (b) Accessibility of site.
- (c) Construction conditions.

- (4) *Economy.* Comparative cost should be weighed on a long-term basis considering the factors given under Index 801.5.

Topic 852 - Design Service Life

852.1 Basic Concepts

The prediction of design service life of drainage facilities is difficult because of the large number of variables, continuing changes in materials, wide range of environments, and use of various protective coatings. The design service life of a drainage facility is defined as the expected maintenance free service life of each installation.

For all metal pipes and arches that are listed in Table 853.1A, maintenance free service life, with respect to corrosion, abrasion and/or durability, is the number of years from installation until the deterioration reaches the point of perforation at any location on the culvert (See Figure 854.3B).

For reinforced concrete pipe (RCP), box (RCB) and arch (RCA) culverts, maintenance free service life, with respect to corrosion, abrasion and/or durability, is the number of years from installation until the deterioration reaches the point of exposed reinforcement at any point on the culvert.

For non-reinforced concrete pipe culverts (NRCP), maintenance free service life, with respect to corrosion, abrasion and/or durability, is the number of years from installation until the deterioration reaches the point of perforation or major cracking with soil loss at any point on the culvert.

For plastic pipe, maintenance free service life, with respect to corrosion, abrasion, and long term structural performance, is the number of years from installation until the deterioration reaches the point of perforation at any location on the culvert or until the pipe material has lost structural load carrying capacity.

Table 851.2
Manning N-Value for Alternative
Pipe Materials⁽¹⁾

Type of Conduit		Recommended Design Value	N-Value Range
Corrugated Metal Pipe ⁽²⁾			
(Annular and Helical) ⁽³⁾			
2 $\frac{2}{3}$ " x $\frac{1}{2}$ "	corrugation	0.025	0.022 - 0.027
3" x 1"	"	0.028	0.027 - 0.028
5" x 1"	"	0.026	0.025 - 0.026
6" x 2"	"	0.035	0.033 - 0.035
9" x 2 $\frac{1}{2}$ "	"	0.035	0.033 - 0.037
Concrete Pipe			
Pre-cast		0.012	0.011 - 0.017
Cast-in-place		0.013	0.012 - 0.017
Concrete Box		0.013	0.012 - 0.018
Plastic Pipe			
Smooth Interior		0.012	0.010 - 0.013
Corrugated Interior		0.022	0.020 - 0.025
Spiral Rib Metal Pipe			
$\frac{3}{4}$ " (W) x 1" (D) @ 11 $\frac{1}{2}$ " o/c		0.013	0.011 - 0.015
$\frac{3}{4}$ " (W) x $\frac{3}{4}$ " (D) @ 7 $\frac{1}{2}$ " o/c		0.013	0.012 - 0.015
$\frac{3}{4}$ " (W) x 1" (D) @ 8 $\frac{1}{2}$ " o/c		0.013	0.012 - 0.015
Composite Steel Spiral Rib Pipe		0.012	0.011 - 0.015
Steel Pipe, Ungalvanized		0.015	--
Cast Iron Pipe		0.015	--
Clay Sewer Pipe		0.013	--

- (1) Tabulated n-values apply to circular pipes flowing full. For noncircular or partially full conduits the tabulated values may be modified as shown in Appendix B of HDS No. 5, Hydraulic Design of Highway Culverts.
- (2) For lined corrugated metal pipe, a composite roughness coefficient may be computed using the procedures outlined in the HDS No. 5, Hydraulic Design of Highway Culverts.
- (3) Lower n-values may be possible for helical pipe under specific flow conditions (refer to FHWA's publication Hydraulic Flow Resistance Factors for Corrugated Metal Conduits), but in general, it is recommended that the tabulated n-value be used for both annular and helical corrugated pipes.

All types of culverts are subject to deterioration from corrosion, or abrasion, or material degradation. Corrosion may result from active elements in the soil, water and/or atmosphere. Abrasion is a result of mechanical wear and depends upon the frequency, duration and velocity of flow, and the amount and character of bedload. Material degradation may result from material quality, UV exposure, or long term material structural performance.

To assure that the maintenance free service life is achieved, alternative metal pipe may require added thickness and/or protective coatings. Concrete pipe may require extra thickness of concrete cover over the steel reinforcement, high density concrete, using mineral admixtures, epoxy coated reinforcing steel, and/or protective coatings. Means for estimating the maintenance free service life of pipe, and techniques for extending the useful life of pipe materials are discussed in more detail in Topic 854.

The design service life for drainage facilities for all projects should be as follows:

(1) Culverts, Drainage Systems, and Side Drains.

- (a) Roadbed widths greater than 28 feet - 50 years.
- (b) Greater than 10 feet of cover - 50 years.
- (c) Roadbed widths 28 feet or less and with less than 10 feet of cover - 25 years.
- (d) Installations under interim alignment - 25 years.

(2) Overside Drains.

- (a) Buried more than 3 feet- 50 years.
- (b) All other conditions, such as on the surface of fill slopes - 25 years.

(3) Subsurface Drains.

- (a) Underdrains within roadbed - 50 years.
- (b) Underdrains outside of roadbed - 25 years.
- (c) Stabilization trench drains - 50 years.

In case of conflict in the design service life requirements between the above controls, the highest design service life is required except for those cases of interim alignment with more than 10 feet of cover. For temporary construction, a lesser design service life than that shown above is acceptable.

Where the above indicates a minimum design service life of 25 years, 50 years may be used. For example an anticipated change in traffic conditions or when the highway is considered to be on permanent alignment may warrant the higher design service life.

Topic 853 - Alternate Materials

853.1 Basic Policy

When two or more materials meet the design service life, and structural and hydraulic requirements, the plans and specifications must provide for alternative pipes, pipe arches, overside drains, and underdrains to allow for optional selection by the contractor.

(1) Allowable Alternatives. A table of allowable alternative materials for culverts, drainage systems, overside drains, and subsurface drains is included as Table 853.1A. This table also identifies the various joint types described in Index 853.1(2) that should be used for the different types of installations.

(2) Joint Requirements. The Standard Specifications set forth general performance requirements for transverse field joints in all types of culvert and drainage pipe used for highway construction, such as corrugated metal pipe, and reinforced and plain concrete pipe.

Table 853.1A indicates the alternative types of joints that are available for different arch and pipe installations. The two joint types specified for culvert and drainage systems are identified as "standard" and "positive".

Table 853.1A
Allowable Alternative Materials

Type of Installation	Service Life (yrs) ¹	Allowable Alternatives	Joint Type		
			Standard	Positive	Downdrain
Culverts & Drainage Systems	50	ASSRP, ASRP, CAP, CASP, CSSRP, CIPCP, CSP, NRCP, SAPP, SSPP, SSRP, RCP, RCB, PPC	X	X	--
Overside Drains	50	CAP, CASP, CSP, PPC	--	--	X
Underdrains	50	PAP, PSP, PPET, PPVCP	X	--	--
Arches (Culverts & Drainage Systems)	50	ACSPA, CAPA, CSPA, RCA, SAPP, SSPPA, SSPA	X	X	--

LEGEND

ACSP A	- Aluminized Corrugated Steel Pipe Arch	PPVCP	- Perforated Polyvinyl Chloride Pipe
ASSRP	- Aluminized Steel Spiral Rib Pipe	PSP	- Perforated Steel Pipe
ASRP	- Aluminum Spiral Rib Pipe	RCA	- Reinforced Concrete Arch
CAP	- Corrugated Aluminum Pipe	RCB	- Reinforced Concrete Box
CAPA	- Corrugated Aluminum Pipe Arch	RCP	- Reinforced Concrete Pipe
CSSRP	- Composite Steel Spiral Rib Pipe	SAPP	- Structural Aluminum Plate Pipe
CASP	- Corrugated Aluminized Steel Pipe, Type 2	SAPP A	- Structural Aluminum Plate Pipe Arch
CIPCP	- Cast-in-Place Concrete Pipe	SSPA	- Structural Steel Plate Arch
CSP	- Corrugated Steel Pipe	SSPP	- Structural Steel Plate Pipe
CSPA	- Corrugated Steel Pipe Arch	SSPPA	- Structural Steel Plate Pipe Arch
NRCP	- Non-Reinforced Concrete Pipe	SSRP	- Steel Spiral Rib Pipe
PAP	- Perforated Aluminum Pipe	X	- Permissible Joint Type for the Type of installation Indicated
PPC	- Plastic Pipe Culvert		
PPET	- Perforated Polyethylene Tubing		

NOTE:

- The design service life indicated for the various types of installations listed in the table may be reduced to 25 years in certain situations. Refer to Index 852.1 for a discussion of service life requirements.

The type of joint required for a particular installation is to be designated on the culvert list.

- (a) **Standard Joints.** The "standard" joint is usually for pipes or arches not subject to large soil movement or disjoining forces. These "standard" joints are satisfactory for ordinarily installations, where tongue and groove or simple slip type joints are typically used. The "standard" joint type is generally adequate for underdrains.
- (b) **Positive Joints.** "Positive" joints are for more adverse conditions such as the need to withstand soil movements or resist disjoining forces. Examples of these conditions are steep slopes, sharp curves, and poor foundation conditions. (See Index 829.2 for additional discussion.) "Positive" joints should always be designated on the culvert list for siphon installations.
- (c) **Downrain Joints.** Pipe "downrain" joints are designed to withstand high velocity flows, and to prevent leaking and disjoining that could cause failure.
- (d) **Joint Properties.** A description of the specified joint properties tabulated on page 453 in Section 61 "Culvert and Drain Pipe Joints" of the Standard Specifications is as follows:
 - **Shear Strength.** The shear strength required of the joint is expressed as a percentage of the calculated shear strength of the pipe at a transverse section remote from the joint. All joints, including any connections must be capable of transferring the required shear across the joint.
 - **Moment Strength.** The moment strength required of the joint is expressed as a percent of the calculated moment capacity of the pipe on a transverse section remote from the joint.
 - **Tensile Strength.** The tensile strength is that which resist the longitudinal force which tends to separate (disjoint) adjacent pipe sections.

- **Joint Overlap.**

Integral Preformed Joint. The Joint overlap is the amount of protection of one culvert barrel into the adjacent culvert barrel by the amount specified for the size of pipe designated.

Any part of an installed joint that has less than 1/4 inch overlap will be considered disjointed. Whenever the plans require that the culvert be constructed on a curve, specially manufactured sections of culvert will be required if the design joint cannot meet the minimum 1/4 inch overlap requirement after the culvert section is placed on the specified curve.

Sleeve Joints. The joint overlap is the minimum sleeve width required to engage both the culvert barrels which are abutted to each other.

- (3) **Joint Performance.** The ability of a pipe joint to prevent the passage of either soil particles or water defines its soiltightness or watertightness. These terms are relative and do not mean that a joint will be able to completely stop the movement of soil or water under all conditions. Any pipe joint that allows significant soil migration (piping) will ultimately cause damage to the embankment, the roadway, or the pipe itself. Therefore, site conditions, such as soil particle size, presence of groundwater, potential for pressure flow, etc., must be evaluated to determine the appropriate joint requirement. Other than solvent or fusion welded joints, almost all joints can exhibit some amount of leakage. Joint performance is typically defined by maximum allowable opening size in the joint itself or by the ability to pass a standardized pressure test. The following criteria should be used, with the allowable joint type(s) indicated on the project plans:

- **Normal Joint.** Many pipe joint systems are not defined as either soiltight or watertight. However, for the majority of applications, such as culverts or storm drains placed in well graded backfill and surrounding soils containing a minimum of fines; no potential for groundwater contact; limited internal pressure,

hydraulic grade line below the pavement grade, etc., this type of joint is acceptable. All currently accepted joint types will meet or exceed "Normal Joint" requirements. The following non-gasketed joint types should not be used beyond the "Normal Joint" criteria range:

CMP

- Annular
- Hat
- Helical
- Hugger
- 2-piece Integral Flange
- Universal

PLASTIC

- Split Coupler
- Bell/Spigot

- Soiltight Joint. This category includes those joints which would provide an enhanced level of security against leakage and soil migration over the normal joint. One definition of a soiltight joint is contained in Section 26.4.2.4(e) of the AASHTO Standard Specifications for Highway Bridges. In part, this specification requires that if the size of the opening through which soil might migrate exceeds 1/8 inch, the length of the channel (length of path along which the soil particle must travel, i.e., the coupling length) must exceed 4 times the size of the opening. Alternatively, AASHTO allows the joint to pass a hydrostatic test (subjected to approx. 4.6 feet of head) without leaking to be considered soiltight. Typical pipe joints that can meet this criteria are:

RCP and NRCP

- Flared Bell
- Flush Bell
- Steel Joint-Flush Bell
- Flared Bell (Type R-3)
- Double Gasket
- Tounge and Groove*
- Self Centering T & G*

CMP and SSRP

- Annular w/gasket
- Hat w/gasket
- Helical w/gasket
- Hugger w/gasket
- 2-piece Int. Fl. w/gasket
- Universal w/gasket

CSSRP

- Cuffed end w/gasket

PLASTIC

- Split Coupler w/gasket (premium)
- Bell/Spigot w/gasket

* Where substantial differential settlement is anticipated, would only meet Normal Joint criteria.

Where soil migration is of concern, but leakage rate is not, a soiltight joint can be achieved in most situations by external wrapping of the joint area with filter fabric (see Index 831.4). Joints listed under both the normal joint and soiltight joint categories, with a filter fabric wrap, would be suitable in these conditions and would not require a gasket or sealant. In many cases, fabric wrapping can be less expensive than a rubber gasket or other joint sealant. Coordination with the District Materials Unit is advised to verify that standard filter fabric described in Standard Specification Section 88-1.03 is of sufficient strength to withstand forces applied during construction (heavier fabric may be specified) and that fabric will effectively screen fine soil particles from passage.

- Watertight Joint. Watertight joints are specified when the potential for soil erosion or infiltration/exfiltration must be restricted, such as for downdrains, culverts in groundwater zones, etc. Watertight joint requirements are typically met by the use of rubber gasket materials as indicated in the Standard Specifications. The watertight certification test described in Standard Specification Section 61 requires that no leakage occur when a joint is tested for a period of 10 minutes while subjected to a head of 10 feet over the crown of the

pipe. This is a test that is typically performed in a laboratory under optimal conditions not typical of those found in the field. Where an assurance of watertightness is needed, a field test should be specified. Designers should be aware that field tests can be relatively expensive, and should only be required if such assurance is critical. A field leakage rate in the range of 700 to 1,000 gallons per inch of nominal diameter per mile of pipe length per day, with a hydrostatic head of 6 feet above the crown of the pipe, is not unusual for joints that pass the watertight certification test, and is sufficiently watertight for well graded, quality backfill conditions. Where conditions are more sensitive, a lower rate should be specified. Rates below 50 to 100 gallons per inch per mile per day are difficult to achieve and would rarely be necessary. For example, sanitary sewers are rarely required to have leakage rates below 200 gallons per inch per mile per day, even though they have stringent health and environmental restrictions. Field hydrostatic tests are typically conducted over a period of 24 hours or more to establish a valid leakage rate. Designers should also be aware that non-circular pipe shapes (CMP pipe arches, RCP oval shapes, etc.) should not be considered watertight even with the use of rubber gaskets or other sealants due to the lack of uniform compression around the periphery of the joint. Additionally, watertight joints specified for pressure pipe or siphon applications must meet the requirements indicated in Standard Specification Sections 65 and 66. Pipe joints that meet Standard Specification Section 61 water-tightness performance criteria are:

- | | |
|--------------|--|
| RCP and NRCP | <ul style="list-style-type: none"> – Flared Bell – Flush Bell – Steel Joint-Flush Bell – Flared Bell (Type R-3) – Double Gasket |
|--------------|--|

- | | |
|--------------|--|
| CMP and SSRP | <ul style="list-style-type: none"> – Hugger Bands (H-10, 12) w/gasket and double bolt bar – Annular Band w/gasket – Two Piece Integral Flange w/sleeve-type gasket* |
| PLASTIC | <ul style="list-style-type: none"> – Bell/Spigot w/gasket |

*Acceptable as a watertight pipe only in down drain applications and in 6, 8 and 10 inch diameters. Factory applied sleeve-type gaskets are to be used instead of O-ring or other sealants.

Table 853.1C provides information to help the designer select the proper joint under most conditions.

- (4) *Design Service Life.* Each pipe type selected as an alternative must have the appropriate protection as outlined in Topic 854 to assure that it will meet the design service life requirements specified in Topic 852. The maximum height of cover must be in accordance with the tables included in Topic 854.
- (5) *Selection of a Specific Material Type.* In the cases listed below, the selection of a specific culvert material must be supported by a complete analysis based on the foregoing factors. All pertinent documentation should be placed on file in the District.
 - Where satisfactory performance for a life expectancy of 25 or 50 years, as defined under design service life, cannot be obtained with certain materials by reason of highly corrosive conditions, severe abrasive conditions, or critical structural and construction requirements.
 - For individual drainage systems such as roadway drainage systems or culverts which operate under hydrostatic pressure or culverts governed by hydraulic considerations and which would require separate design for each culvert type.

- When alterations or extensions of existing systems are required, the culvert type may be selected to match the type used in the existing system.

853.2 Alternative Selection

Each alternative material selected for a drainage facility must provide the required design service life based on physical and structural factors, be of adequate size to satisfy the hydraulic design, and require the minimum of maintenance and construction cost for each site condition.

853.3 Alternative Pipe Culvert and Pipe Arch Culvert List

Table 853.3 shows a method of designating the type of material, size, class, thickness, protection, etc., for each type of allowable material. A similar table should be included in the plans adjacent to the drainage list when alternative materials are allowed. Because of the difference in roughness coefficients between various materials, it may be necessary to specify a different size for each allowable material at any one location. In this event, it is recommended that the material with the smallest dimension be listed as the alternative size. Refer to Drafting and Plans Manual for standard format to be used.

There may be situations where there is a different set of alternatives for the same nominal size of alternative drainage facilities. In this case the different sets of the same nominal size should be further identified by different types, for example, 18-inch alternative pipe culvert (Type A), 18-inch alternative pipe culvert (Type B), etc. No attempt to correlate type designation between projects is necessary. The first alternative combination for each culvert size on each project should be designated as Type A, second as Type B, etc.

Since the available nominal sizes for pipe arches vary slightly between pipe arch materials, it is recommended that the listed alternative pipe arch sizes conform to those sizes shown for corrugated steel pipe arches shown on Table 854.3E. The designer should verify the availability of reinforced concrete pipe arches. If reinforced concrete pipe arches are not available, oval shaped reinforced concrete pipe of a size necessary to meet the

hydraulic requirements may be used as an alternative.

Topic 854 - Kinds of Pipe Culverts

854.1 Reinforced Concrete Pipe

(1) *Durability.* RCP is generally precast prior to delivery to the project site. The durability of reinforced concrete pipe can be affected by acids, chlorides and sulfate in the soil and water. Table 854.1A indicates the limitation on the use of concrete by acidity of soil and water. Table 854.1A is also a guide for designating cementitious material restrictions and water content restrictions for various ranges of sulfate concentrations in soil and water. Unfortunately, the CULVERT 4 computer program should not be used to estimate service life for concrete culverts because the current version has not been updated to include the most recent recommendations of the corrosion unit. However, as discussed in Topic 854.3, CULVERT 4 can still be used to estimate service life of corrugated metal pipe. In addition to the protective measures noted above, the following measures increase the durability of reinforced concrete culverts.

(a) *Cover Over Reinforcing Steel.* Additional cover over the reinforcing steel should be specified where abrasion is likely to be so severe as to appreciably shorten the design service life of a concrete culvert. This extra cover is also warranted under exposure to corrosive environments (see Table 854.1B). Extra cover over the reinforcing steel does not necessarily require extra wall thickness, as it may be possible to provide the additional cover and still obtain the specified D-load with standard wall thicknesses.

(2) *Strength Requirements.*

(a) *Design Standards.* The strength of reinforced concrete pipe is determined by the load to produce a 0.01 inch crack under the 3-edge bearing test called for in AASHTO Designations M 170M, M 207M, and M 206M for circular reinforced pipe,

Table 853.1C
Joint Selection Criteria

<u>JOINT TYPE</u> ⇒ ⇓ <u>SITE CONDITIONS</u>	“NORMAL” JOINT	“SOILTIGHT” JOINT	“WATERTIGHT” JOINT
<u>SOIL FACTORS</u>			
Limited potential for soil migration (e.g., gravel, medium to coarse sands, cohesive soil)	X	X	X
Moderate potential for soil migration (e.g., fine sands, silts)	X ⁽¹⁾	X	X
High potential for soil migration (e.g., very fine sands, silts of limited cohesion)		X ⁽¹⁾	X ⁽¹⁾
<u>INFILTRATION / EXFILTRATION</u>			
No concern over either infiltration or exfiltration.	X	X	X
Infiltration or exfiltration not permitted (e.g., potential to contaminate groundwater, contaminated plume could infiltrate)			X ⁽²⁾
<u>HYDROSTATIC POTENTIAL</u>			
Installation will rarely flow full. No contact with groundwater.	X	X	X
Installation will occasionally flow full. Internal head no more than 10 feet over crown. No potential groundwater contact.		X	X
Installation may or may not flow full. Internal head no more than 10 feet over crown. May contact groundwater.			X
Possible hydrostatic head (internal or external) greater than 10 feet, but less than 25 ft ⁽³⁾ .			X ⁽²⁾

“X” indicates that joint type is acceptable in this application. The designer should specify the most cost-effective option.

¹ Designer should specify filter fabric wrap at joint. See Index 831.4.

² Designer should consider specifying field watertightness test.

³ Pipe subjected to hydrostatic heads greater than 25 ft should have joints designed specifically for pressure applications.

Table 853.3
Example Listing of Alternative Pipe
Culverts and Pipe Arch Culverts

ALLOWABLE PIPE MATERIAL AND PROTECTION															
	RCP ⁽¹⁾	CSP				CAP				CSSRP		RCB		PLASTIC	
Designation	Size (in)	Size (in)	Thick. (in)	Bitum. Coating	Bitum. Coat Pav'd Inv.	Size (in)	Thick. (in)	Bitum. Coating	Bitum. Coat Pav'd In.	Size (in)	Thick. (in)	Span x Ht. (ft)	Max. Cover (ft)	Corrug. Inter. ⁽³⁾ (in)	Smooth Inter. ^{(3),(4)} (in)
18" Alt. Pipe (Type A)	18	18	0.064	No	No	18	0.060	No	No	--	--	--	--	18	18
18" Alt. Pipe (Type B)	18	24	0.064	Yes	No	24	0.060	No	No	--	--	--	--	24	18
24" Alt. Pipe (Type A)	24	24	0.064	Yes	Yes	24	0.060	No	No	--	--	--	--	24	24
24" Alt. Pipe (Type B)	24	30	0.079	No	No	--	--	--	--	--	--	--	--	--	24
24" Alt. Pipe (Type C)	--	24	0.079	No	No	24	0.135	No	No	--	--	--	--	--	--
36" Alt. Pipe (Type A)	36	42	0.064	Yes	Yes	42	0.135	No	No	36	0.064	--	--	--	--
36" Alt. Pipe (Type B)	36	36	0.079	Yes	No	36	0.105	No	No	36	0.064	--	--	--	36
48" Alt. Pipe (Type A)	48	48	0.064	Yes	Yes	48	0.105	No	No	48	0.064	--	--	--	48
48" Alt. Pipe (Type B)	48	54	0.079	No	No	54	0.135	No	No	48	0.064	--	--	--	--
49" x 33" Alt. Pipe Arch	--	49 x 33	0.079	Yes	No	49 x 33	0.105	No	No	49 x 33	0.079	--	--	--	--
60" Alt. Pipe	60	66	0.079	No	No	66	0.105	No	No	60	0.079	--	--	--	--
78" Alt. Pipe (Type A)	78	5 x 1 78	0.109	No	No	78	0.135	No	No	78	0.109	--	--	--	--
78" Alt. Pipe (Type B)	78	3 x 1 78	0.079	Yes	Yes	--	--	--	--	78	0.109	6 x 6	20	--	--

NOTES:

- (1) See Standard Plan A62D for RCP strength classification and method of backfill.
- (2) Coupler Type must be shown on Culvert List. (S=Standard, P=Positive, D=Down drain)
- (3) See Standard Specifications Section 64-1.03 for available and allowable plastic pipe sizes.
- (4) Smooth interior plastic pipe may be either Type S or Type D HDPE; Ribbed HDPE; or Ribbed PVC pipe at the contractors option. See Section 64 of the Standard Specifications.

oval shaped reinforced pipe, and reinforced concrete pipe arches, respectively.

- (b) Height of Fill. See Standard Plan A62D and A62DA for the maximum height of overfill for reinforced concrete pipe, up to and including 108-inch diameter (or reinforced oval pipe and reinforced concrete pipe arch with equivalent cross-sectional area), using the backfill method specified in Standard Specification Section 19-3.06, Structure Backfill.

The designer should be aware of the premises on which the tables on Standard Plan A62D and A62DA are computed as well as their limitations. The fill heights presupposes:

- That the bedding and backfill satisfy the terms of the Standard Specifications, the conditions of cover and pipe size required by the plans, and take into account the essentials of Index 829.2.
- That a small amount of settlement will occur under the culvert equal in magnitude to that of the adjoining material outside the trench.
- Subexcavation and backfill as required by the Standard Specifications where unyielding foundation material is encountered.

(c) Special Designs.

- If the height of overfill exceeds the tabular values on Standard Plan A62D and A62DA a special design is required; see Index 829.2.
- Where severe abrasion or wear from high velocity is anticipated, at least 2 inches of cover over the reinforcing steel must be specified by special provision. Specifying thick wall pipe will not assure 2 inches of cover over reinforcing steel. Concrete is generally more resistant to abrasion from sand bedloads and more susceptible to abrasion from rock bedloads. For additional assistance, contact District

Hydraulics or the Office of State Highway Drainage Design.

- In corrosive environments, consideration must be given to the requirements of Index 854.1(1).

- (3) *Shapes.* Reinforced concrete culverts are available in circular and oval shapes. Reinforced concrete pipe arch (RCPA) shapes have been discontinued by West Coast manufacturers.

In general, the circular shaped is the most economical for the same cross-sectional area. Oval shapes are appropriate for areas with limited head or overfill or where these shapes are more appropriate for site conditions. A convenient reference to commercially available products and shapes is the AASHTO publication, "A Guide to Standardized Highway Drainage Products".

- (4) *Invert Protection.* Invert protection should be considered for culverts exposed to excessive wear from abrasive flows or corrosive water. Continued maintenance can be expected if the culvert is not adequately designed for severe abrasion or corrosion. When severe abrasion or corrosion is anticipated, special designs should be investigated and considered. Higher initial costs can probably be justified on the basis it would be more economical than later repair or replacement costs. Typical invert protection includes increased wall thickness, invert paving with portland cement concrete with wire mesh reinforcement, and invert lining with metal plate, channel iron, or rails. Invert linings should cover the lower fourth of the periphery of circular pipes, and the lower third of pipe arches.

- (5) *Non-Reinforced Concrete Pipe Option.* Non-reinforced concrete pipe may be substituted at the contractors option for reinforced concrete pipe for all sizes 36 inches in diameter and smaller as long as it conforms to Section 65 of the Standard Specifications. Non-Reinforced concrete pipe is not affected by chlorides or stray currents and may be used in lieu of RCP in these environments without coating or the need to provide extra cover over reinforcement.

(6) *Direct Design Method - RCP.* (Contact Division of Structures)

854.2 Cast-in-Place Non-reinforced Concrete Pipe

(1) *Design Criteria.*

- (a) Use of cast-in-place concrete pipe should not be considered when an unstable trench condition occurs; for example, it should not be installed under the following conditions.
 - Sandy and cohesionless soil.
 - Shallow location in expansive soil where the volume change would crack pipe.
 - Areas where ground is subject to freezing to considerable depths for lengthy periods.
 - Marshy, tidal areas and other areas of subsidence or differential settlement.
 - Locations near geologic faults or where potential for liquefaction exists.
- (b) Cover between top of pipe and ground surface should be at least 2.5 feet, or 2 feet below the grading plane. In expansive soils, cover should be a minimum of 3 feet. Some special treatment may be needed in expansive soil, depending on moisture content.
- (c) Cast-in-place concrete pipe may be used only if static head is intermittent and less than 12 feet above center of pipe, and some leakage is acceptable.
- (d) Installation under any State Highway Roadbed is only permissible with FHWA and/or headquarters and the Division of Structures approval. Installations outside the roadbed are permissible, but the possibility of future widenings should be considered prior to finalizing the culvert location.
- (e) A guide to cementitious material restrictions and water content restrictions to be used

with various ranges of sulfated concentrations in the soil and water are shown in Table 854.1A. See Table 854.1A for limitations of use due to soil and water acidity. Also, Topic 854.1(4) provides additional guidance for abrasion and invert protection.

- (2) *Height of Fill.* The maximum allowable height of cover for cast-in-place concrete pipe is given in Table 854.2. The designer should review Standard Plan A62-D for additional installation criteria.

854.3 Corrugated Steel Pipe, Steel Spiral Rib Pipe and Pipe Arches

- (1) *Hydraulics.* Corrugated steel pipe comes in various corrugated profiles. Annular and helical corrugated steel pipe configurations are applicable in the situations where velocity reduction is important or if a culvert is being designed with an inlet control condition. Spiral rib pipe, on the other hand, may be more appropriate for use in stormdrain situations or if a culvert is being designed with an outlet control condition.
- (2) *Durability.* The anticipated maintenance free service life of corrugated steel pipe, steel spiral rib pipe and pipe arch installations is primarily a function of the corrosivity and abrasiveness of the environment into which the pipe is placed. Corrosion potential must be determined from the pH and minimum resistivity tests covered in California Test 643. Abrasive potential must be estimated from bed material that is present and anticipated flow velocities. Refer to Topic 852.1 for a discussion of maintenance free service life.

Consideration should be given to specifying alternative designs when it is possible to achieve the required design service life by first considering protective coatings and if the design service life has not been achieved, increasing the metal thickness.

Table 854.1A
Guide for the Protection of Reinforced and Unreinforced
Concrete Against Acid and Sulfate Exposure Conditions^(a,b)

Soil or Water pH	Sulfate Concentration of Soil or Water (ppm)	Cementitious Material Restrictions	Water Content Restrictions
7.1 to 14	0 to 1,500	No Restrictions	No Restrictions
5.6 to 7.0	Greater Than 1,500 to 2,000	No Restrictions	Maximum water-to-cementitious material ratio of 0.45
3 to 5.5 ^(d)	Greater Than 2,000 to 15,000 ^(d)	675 lb/cy minimum: 75% Type II Mod. or Type V 25% mineral admixture ^(c)	Maximum water-to-cementitious material ratio of 0.40

NOTE:

- (a) Recommendations shown in the table for the cementitious material restrictions and water content restrictions should be used if the pH and/or the sulfate conditions in Column 1 and/or Column 2 exists. Sulfate testing is not required if the minimum resistivity is greater than 1,000 ohm-cm.
- (b) The table lists soil/water pH and sulfate concentration in increasing level of severity starting from the top of the table. If the soil/water pH and the sulfate concentration are at different levels of severity, the recommendation for the more severe level will apply. For example, a soil with a pH of 4.0, but with a sulfate concentration of only 1,600 ppm would require a minimum of 675 lb/cy of cementitious material. The cementitious material would consist of 75% by mass Type II Modified or Type V cement plus 25% by mass mineral admixture. The maximum water-to-cementitious material ratio would be 0.40.
- (c) Mineral admixtures shall conform to ASTM Designation: C618 and Section 90-4.02 of Caltrans Standard Specifications.
- (d) Additional mitigation measures will be needed for conditions where the pH is less than 3 and/or the sulfate concentration exceeds 15,000 ppm. Mitigation measures may include additional concrete cover and/or protective coatings. For additional assistance, contact the Corrosion Technology Branch or the Office of Rigid Pavement Materials and Structural Concrete of the Division of Materials Engineering and Testing Services (METS) at 5900 Folsom Boulevard Sacramento, CA. 95819.

Table 854.2
Cast-in-Place Concrete Pipe
Fill Height Table

Diameter. (in)	Concrete Strength (psi)			
	3,500	4,000	4,500	5,000
	Maximum Fill Height (ft)			
30	13	13	14	15
36	12	13	14	15
42	11	12	13	14
48	13	14	15	16
54	13	14	15	16
60	12	13	14	15
66	12	13	14	15
72	11	12	13	14
78	11	12	13	14
84	11	12	13	14

The following measures are commonly used to prolong the maintenance free service life of steel culverts:

- (a) Galvanizing. Under most conditions plain galvanizing of steel pipe is all that is needed; however, the presence of corrosive or abrasive elements may require additional protection.
 - Protective Coatings - The necessity for any coating should be determined considering hydraulic conditions, local experience, possible environmental impacts, and long-term economy. Approved protective coatings are bituminous asphalt, which is hot-dipped to cover the entire inside and outside of the pipe; asphalt mastic and polymeric sheet, which can be applied to the inside and/or outside of the pipe; and

polymerized asphalt, which is hot-dipped to cover the bottom 90° of the inside and outside of the pipe. All of these protective coatings are typically shop-applied prior to delivery to the construction site. A polymeric sheet coating provides much improved corrosion resistance over bituminous coatings and can be considered to typically allow achievement of a 50-year maintenance free service life without need to increase thickness of the steel pipe. To ensure that a damaged coating does not lead to premature catastrophic failure, the base steel thickness for pipes that are to be coated with a polymeric sheet must be able to provide a minimum 10-year service life prior to application of the polymeric material. In addition, a bituminous lining or bituminous paving can be applied over a bituminous coating primer on the inside of the pipe for extra corrosion or abrasion protection (see Standard Specification 66-1.03, paragraphs 4 and 5).

Citing Section 5650 of the Fish and Game Code, the Department of Fish and Game (DFG) may restrict the use of bituminous coatings on the interior of pipes if they are to be placed in streams which flow continuously or for an extended period (more than 1 to 2 days) after a rainfall event. Their concern is that abraded particles of asphalt could enter the stream and degrade the fish habitat. Where abrasion is unlikely, DFG concerns should be minimal. DFG has indicated that they have no concerns regarding interior application of polymerized asphalt or polymeric sheet coatings, even under abrasive conditions.

Where the materials report indicates that soil side corrosion is expected, a bituminous asphalt coating (i.e., hot-dipped) or an exterior application of polymeric sheet, as provided in the Standard Specifications, combined with galvanizing of steel, is usually effective in

forestalling accelerated corrosion on the backfill side of the pipe. Where soil side corrosion is the only concern, exterior bituminous asphalt protection (i.e., hot-dipped) may provide up to 25 years and a polymeric sheet coating may provide up to 50 years of additional service life. For locations where water side corrosion and/or abrasion is of concern, protective coatings, or protective coatings with pavings, or protective coatings with linings, in combination with galvanizing will add to the culvert service life to a variable degree, depending upon site conditions and type of coating selected. In addition, composite steel spiral ribbed pipe which is a steel spiral ribbed pipe externally precoated with a polymeric sheet, and internally polyethylene lined, may also provide additional service life. If hydraulic conditions at the culvert site require a lining on the inside of the pipe or a coating different than that indicated in the Standard Specifications, then the different requirements must be described in the Special Provisions.

- **Extra Metal Thickness.** Added service life can be achieved by adding metal thickness. However, this should only be considered after protective coatings and pavings have been considered. Since 0.052 inch thick steel culverts is the minimum steel pipe Caltrans allows, it must be limited to locations that are nonabrasive.

Table 854.3A constitutes a guide for estimating the added service life that can be achieved by coatings and invert paving of steel pipes based upon abrasion resistance characteristics. However, the table does not quantify added service life of coatings and paving of steel pipe based upon corrosion protection. Recently developed coating products, like polymerized asphalt and polymeric sheet, can provide superior abrasive resistant qualities (as much as 10 or more times that of bituminous coatings of similar thickness). In heavily abrasive situations, concrete inverts should be

considered. The guide values for years of added service life should be modified where field observations of existing installations show that other values are more accurate. The designer should be aware of the following limitations when using Table 854.3A:

- **Channel Materials:** If there is no existing culvert, it may be assumed that the channel is potentially abrasive to culvert if sand and/or rocks are present. Presence of silt, clay or heavy vegetation may indicate a non-abrasive flow.
 - **Flow velocities:** For continuous and substantial flow, the years of invert protection can be expected to be one-half of that shown. For the more typical intermittent flow, the velocities indicated in the table should be compared to those generated by the 2-5 year return frequency flood.
- (b) **Aluminized Steel (Type 2).** Evaluations of aluminized steel (type 2) pipe in place for over 40 years have provided data that substantiate a design service life with respect to corrosion resistance equivalent to aluminum pipe. Therefore, for pH values between 5.5 and 8.5, and minimum resistivity values in excess of 1500 ohm-cm, 0.064 inch aluminized steel (type 2) is considered to provide a 50 year design service life. Where abrasion is of concern, aluminized steel (type 2) is considered to be roughly equivalent to galvanized steel. Bituminous coatings are not recommended for corrosion protection, but may be used in accordance with Table 854.3A for abrasion resistance. For pH ranges outside the 5.5 and 8.5 limits or minimum resistivity values below 1500 ohm-cm, aluminized steel (type 2) should not be used. In no case should the thickness of aluminized steel (type 2) be less than the minimum structural requirements for a given diameter of galvanized steel.

Figure 854.3B should be used to determine the minimum thickness and limitation on the use of corrugated steel and spiral rib pipe for various

levels of pH and minimum resistivity. For example, given a soil environment with pH and minimum resistivity levels of 6.5 and 15,000 ohm-cm, respectively, the minimum thicknesses for the various metal pipes are: 1) 0.109 inch (12 gage) galvanized steel, 2) 0.064 inch (16 gage) aluminized steel (type 2) and 3) 0.060 inch (16 gage) aluminum. The minimum thickness of metal pipe obtained from the figure only satisfies corrosion requirements. Overfill requirements for minimum metal thickness must also be satisfied. The metal thickness of corrugated pipe and steel spiral rib pipe that satisfies both requirements should be used.

The CULVERT4 Computer Program, or subsequent upgrades, is also available to help designers estimate service life for various corrosive/abrasive conditions. This program can be obtained from the District Materials Engineer or for purchase from Mctrans (refer to Topic 807.4).

Figure 854.3C, "Chart for Estimating Years to Perforation of Steel Culverts," is part of a Standard California Department of Transportation Test Method derived from highway culvert investigations. This chart alone is not used for determining service life because it does not consider the effects of abrasion or overfill; it is for estimating the years to the first corrosion perforation of the wall or invert of the CSP.

(3) *Strength Requirements.* The strength requirements for corrugated steel pipes and pipe arches, fabricated under acceptable methods contained in the Standard Specifications, are given in Tables 854.3B, C, D, & E. For steel spiral rib pipe see Tables 854.3F, G & H.

(a) Design Standards.

- Corrugation Profiles - Corrugated steel pipe and pipe arches are available in $2\frac{2}{3}$ " x $\frac{1}{2}$ ", 3" x 1", and 1" x 1" profiles with helical corrugations, and $2\frac{2}{3}$ " x $\frac{1}{2}$ " profiles with annular corrugations. Corrugated steel spiral rib pipe is available in a $\frac{3}{4}$ " x $\frac{3}{4}$ " x $7\frac{1}{2}$ " or $\frac{3}{4}$ " x 1" x $11\frac{1}{2}$ " helical corrugation pattern. For systems requiring large

diameter and/or deeper fill capacity a $\frac{3}{4}$ " x 1" x $8\frac{1}{2}$ " helical corrugation pattern is available. Composite steel spiral rib pipe is available in a $\frac{3}{4}$ " x $\frac{3}{4}$ " x $7\frac{1}{2}$ " helical ribbed profile.

- Metal Thickness - Corrugated steel pipe and pipe arches are available in the thickness as indicated on Tables 854.3B, C, D & E. Corrugated steel spiral rib pipe is available in the thickness as indicated on Tables 854.3F, G & H. Where a maximum overfill is not listed on these tables, the pipe or arch size is not normally available in that thickness. Corrugated steel spiral rib pipe is available in the thickness as indicated on Tables 854.3F, G & H. Composite steel spiral rib pipe is available in the thickness as indicated on Table 854.3H.
 - Height of Fill - The allowable overfill heights for corrugated steel and corrugated steel spiral rib pipe and pipe arches for the various diameters or arch sizes and metal thickness are shown on Tables 854.3B, C, D, & E. For corrugated steel spiral rib pipe, overfill heights are shown on Tables 854.3F, G & H. Table 854.3H gives the allowable overfill height for composite steel spiral rib pipe.
- (b) Basic Premise. To properly use the above mentioned tables, the designer should be aware of the premises on which the tables are based as well as their limitations. The design tables presuppose:
- That bedding and backfill satisfy the terms of the Standard Specifications, the conditions of cover, and pipe size required by the plans and the essentials of Index 829.2.
 - That a small amount of settlement will occur under the culvert, equal in magnitude to that of the adjoining material outside the trench.
- (c) Limitations. In using the tables, the following restrictions must be kept in mind.
- The values given for each size of pipe constitute the maximum height of

overfill or cover over the pipe for the thickness of metal and kind of corrugation.

- The thickness shown is the structural minimum. Where abrasive conditions are anticipated, additional metal thickness or invert treatments as stated under Index 854.3(5) should be provided when required to fulfill the design service life requirements of Topic 852.
- Where needed, adequate provisions for corrosion resistance must be made to achieve the required design service life called for in the references mentioned herein.
- Table 854.3E shows the limit of heights of cover for corrugated steel pipe arches based on the supporting soil sustaining a bearing pressure varying between $2\frac{1}{2}$ tons per square feet to $4\frac{1}{4}$ tons per square feet. Table 854.4C shows similar values for corrugated aluminum pipe arches.

(d) Special Designs.

- If the height of overfill exceeds the tabular values, or if the foundation investigation reveals that the supporting soil will not develop the bearing pressure on which the overfill heights for pipe arches are based, a special design prepared by the Division of Structures is required.
- Non-standard pipe diameters and arch sizes are available. Loading capacity of special designs needs to be verified with the Underground Structures Branch of the Division of Structures.

(4) *Shapes.* Corrugated steel pipe, steel spiral rib pipe and pipe arches are available in the diameters and arch shapes as indicated on the maximum height of cover tables. For larger diameters, arch spans or special shapes, see Index 854.6.

(5) *Invert Protection.* Invert protection should be considered for corrugated steel culverts exposed to excessive wear from abrasive flows or corrosive water. Severe abrasion usually occurs

when the flow velocity exceeds 15 feet per second and contains a bedload. When severe abrasion or corrosion is anticipated, special designs should be investigated and considered. Typical invert protection includes invert paving with asphalt concrete or portland cement concrete with wire mesh reinforcement, and invert lining with metal plate, channel iron, or rails. Invert linings should cover the lower fourth of the periphery of circular pipes, and the lower third of pipe arches. Additional metal thickness will increase service life. Reducing the velocity within the culvert is an effective method of preventing severe abrasion. Topic 854.3(2) provides additional guidance on invert protection.

(6) *Spiral Rib Steel.* Galvanized steel spiral rib pipe is fabricated using sheet steel and lock seam fabrication as used for helical corrugated metal pipe. The thickness of metal and zinc coating is identical to that for corrugated pipe. Spiral rib pipe has a lower roughness coefficient (Manning's "n") than corrugated metal pipe.

Aluminized steel spiral rib pipe, type 2 (ASSRP) is available in the same sizes as galvanized steel spiral rib and will support the same fill heights (the aluminizing is simply a replacement coating for zinc galvanizing that allows thinner steel to be placed in certain corrosive environments - See Figure 854.3B for the acceptable pH and resistivity ranges for placement of aluminized steel pipes). Tables 854.3F, G & H give the maximum height of overfill for steel spiral rib pipe constructed under the acceptable methods contained in the Standard Specifications and essentials discussed in Index 829.2.

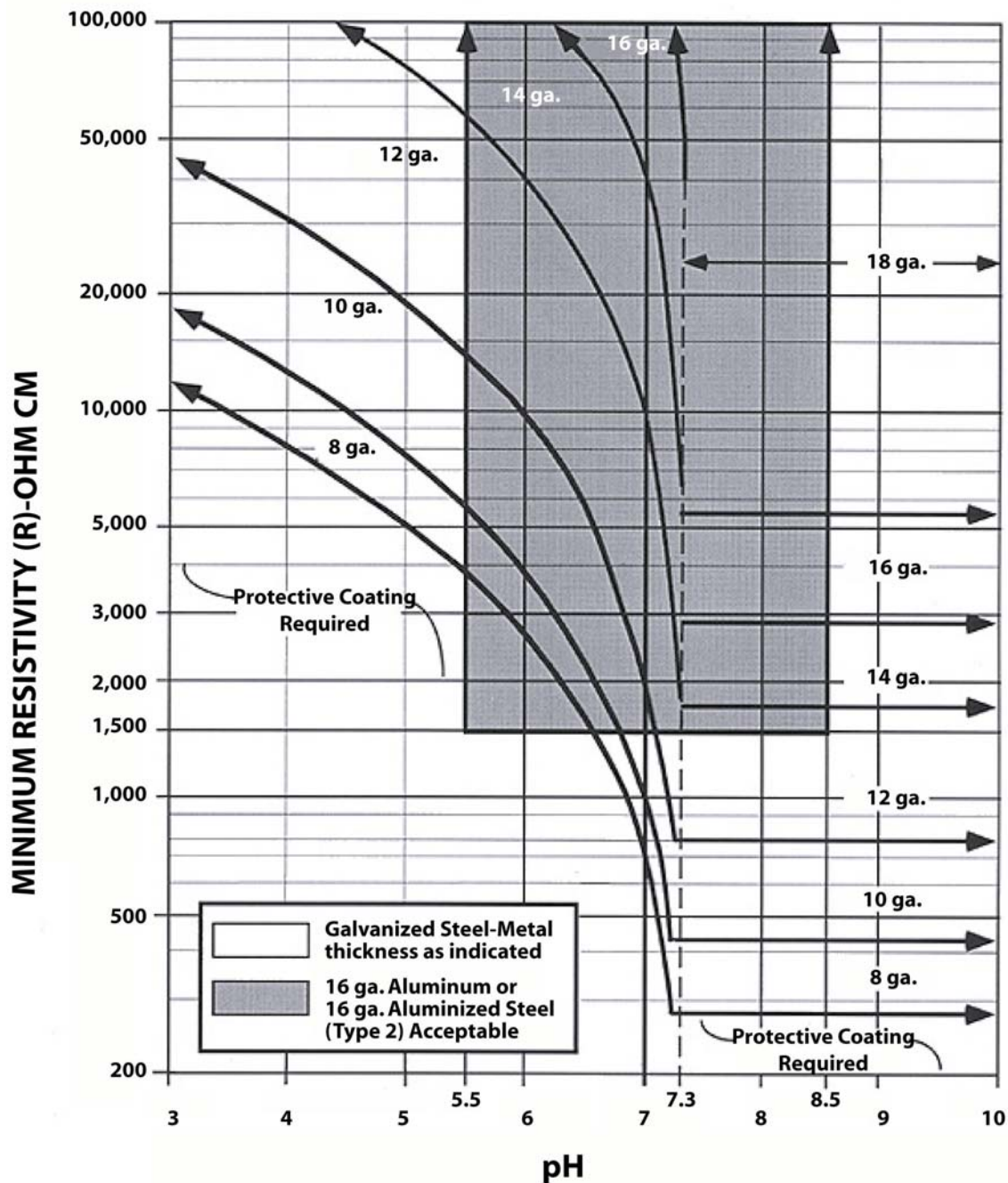
Table 854.3A
Guide for Anticipated Service
Life Added to Steel Pipe by
Abrasive Resistant Protective Coating

Flow Vel. (ft/s)	Channel Materials	Bituminous Coating (yrs.) (hot-dipped)	Bituminous Coating & Paved Invert (yrs.)	Polymerized Asph. (yrs.) (hot-dipped)	Polymeric Sheet Coating. (yrs.)	Composite SSRP
	Non- Abrasive	8	15	*	*	*
<5.0	Abrasive	6	15	*	*	*
5.0 - 15	Abrasive	0-6	2-12	10-40	10-40	20-50
>15	Abrasive	**	**	**	**	**

* Polymeric sheet coating or polymerized asphalt invert coating provides adequate abrasion resistance to meet or exceed a 50 year design service life.

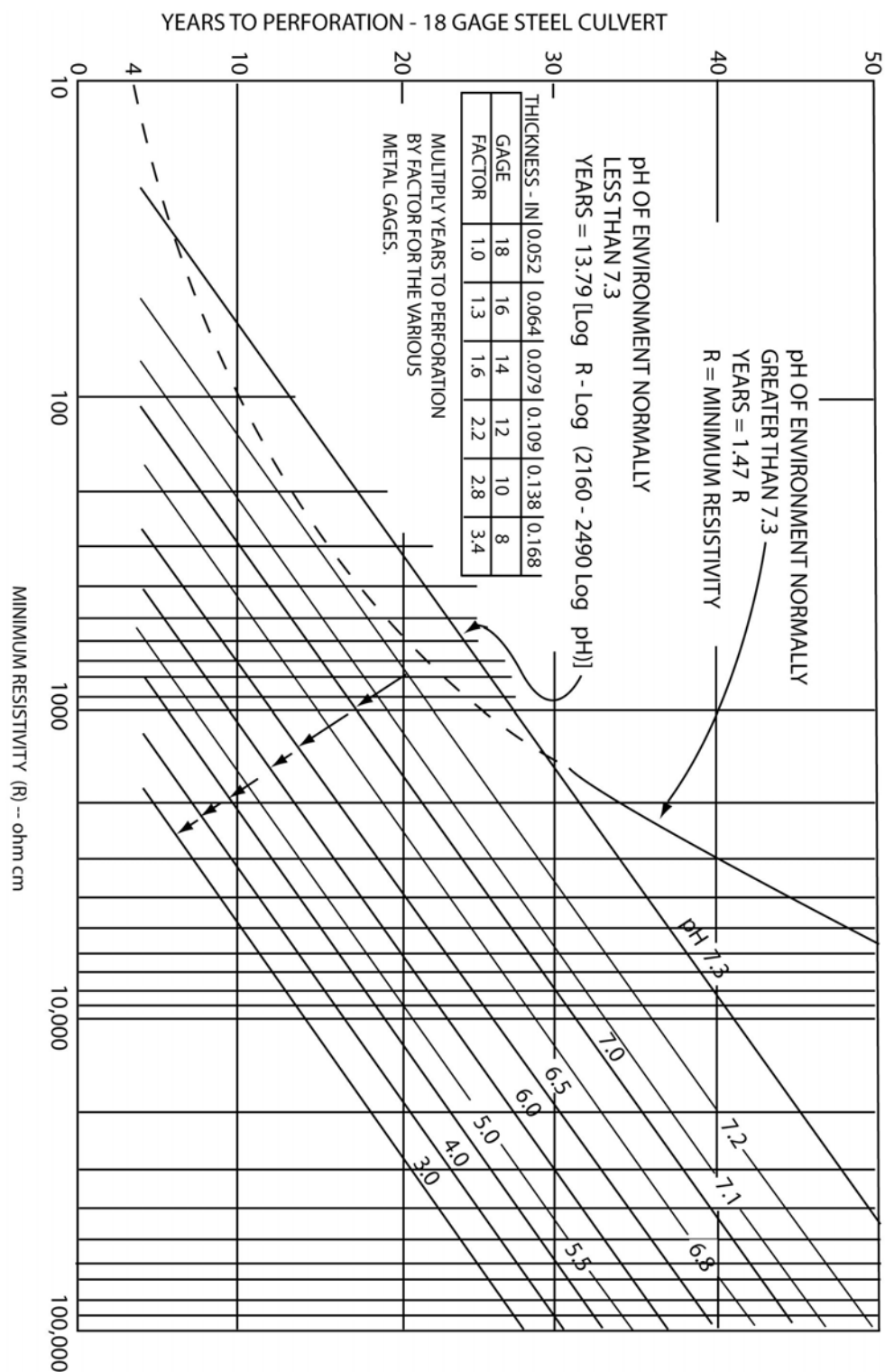
** None of the listed abrasive resistant protective coatings recommended, contact District Hydraulics Branch.

Figure 854.3B
Minimum Thickness of Metal Pipe
for 50 Year Maintenance Free Service Life (2)



- Notes:
1. For pH and minimum resistivity levels not shown refer to Fig. 854.3C steel pipes. (California Test 643)
 2. Service life estimate are for various corrosive conditions only.
 3. Refer to index 854.3(2) and 854.4(2) for appropriate selection of metal thickness and protection coating to achieve service life requirements.

Figure 854.3C
Chart for Estimating Years
to Perforation of Steel Culverts



854.4 Corrugated Aluminum Pipe, Aluminum Spiral Rib Pipe and Pipe Arches

(1) *Hydraulics.* Corrugated aluminum pipe comes in various corrugated profiles. Annular and helical corrugated aluminum pipe configurations are applicable in the situations where velocity reduction is important or if a culvert is being designed with an inlet control condition. Spiral rib pipe, on the other hand, may be more appropriate for use in stormdrain situations or if a culvert is being designed with an outlet control condition.

(2) *Durability.* Aluminum culverts or stormdrains may be specified as an alternate culvert material. When a 50-year maintenance free service life of aluminum pipe is required the pH and minimum resistivity, as determined by California Test Method 643, must be known and the following conditions met:

- (a) The pH of the soil, backfill, and effluent is within the range of 5.5 and 8.5, inclusive. Bituminous coatings are not recommended for corrosion protection or abrasion resistance.
- (b) The minimum resistivity of the soil, backfill, and effluent is 1500 ohm-centimeters or greater.
- (c) Under similar conditions, aluminum culverts will abrade approximately three times faster than steel culverts. Therefore, aluminum culverts are not recommended where abrasive materials are present, and where flow velocities would encourage abrasion to occur. Culvert flow velocities that frequently exceed 5 feet per second should be carefully evaluated prior to selecting aluminum as an allowable alternate.
- (d) Aluminum culverts should not be installed in an environment where other aluminum culverts have exhibited significant distress, such as extensive perforation or loss of invert, for whatever reason, apparent or not.
- (e) Aluminum may be considered for side drains in environments having the following parameters:

- When pH is between 5.5 and 8.5 and the minimum resistivity is between 500 and 1500 ohm-cm.
- When pH is between 5.0 and 5.5 or between 8.5 and 9.0 and the minimum resistivity is greater than 1500 ohm-cm.

For these conditions, the METS should be contacted to confirm the advisability of using aluminum on specific projects.

- (f) Aluminum must not be used as a section or extension of a culvert containing steel sections.

Figure 854.3B should be used to determine the limitations on the use of corrugated aluminum pipe for various levels of pH and minimum resistivity. The minimum thickness (0.060 inch) of aluminum pipe obtained from the chart only satisfies corrosion requirements. Overfill requirements for minimum metal thickness must also be satisfied. The metal thickness of corrugated aluminum pipe should satisfy both requirements.

- (3) *Strength Requirements.* The strength requirements for corrugated aluminum pipe and pipe arches fabricated under the acceptable methods contained in the Standard Specifications, are given in Tables 854.4A, B & C. For aluminum spiral rib pipe, see Tables 854.4D & E.

(a) Design Standards.

- *Corrugation Profiles* - Corrugated aluminum pipe and pipe arches are available in 2 $\frac{2}{3}$ " x $\frac{1}{2}$ " and 5" x 1" profiles with helical or annular corrugations. Aluminum spiral rib pipe is available in a $\frac{3}{4}$ " x $\frac{3}{4}$ " x 7 $\frac{1}{2}$ " or a $\frac{3}{4}$ " x 1" x 11 $\frac{1}{2}$ " helical corrugation profile.
- *Metal thickness* - Corrugated aluminum pipe and pipe arches are available in the thickness as indicated on Tables 854.4A, B & C. Where a maximum overfill is not listed on these tables, the pipe or pipe arch is not normally available in that thickness. Aluminum spiral rib pipe are

available in the thickness as indicated on Tables 854.4D & E.

- **Height of Fill** - The allowable overflow heights for corrugated aluminum pipe and pipe arches for various diameters and metal thickness are shown on Tables 854.4A, B & C. For aluminum spiral rib pipe, overflow heights are shown on Tables 854.4D, & E.

To properly use the above mentioned tables, the designer should be aware of the basic premises on which the tables are based as well as their limitations. (See Index 854.3(2)).

- (4) *Shapes*. Corrugated aluminum pipe, aluminum spiral rib pipe and pipe arches are available in the diameters and arch shapes as indicated on the maximum height of cover tables. Helical corrugated pipe must be specified if anticipated heights of cover exceed the tabulated values for annular corrugated pipe.

For larger diameters, arch spans or special shapes, see Index 854.6. Non-standard pipe diameters and arch sizes are also available.

- (5) *Invert Protection*. Invert protection of corrugated aluminum is not recommended.
- (6) *Spiral Rib Aluminum*. Aluminum spiral rib pipe is similar to spiral rib steel. Figure 854.3B should be used to determine the limitations on the use of spiral rib aluminum pipe for the various levels of pH and minimum resistivity. Tables 854.4D & E give the maximum overflow for aluminum spiral rib pipe constructed under the acceptable methods contained in the Standard Specifications and the essentials discussed in Index 829.2.

854.5 Special Purpose Types

- (1) *Smooth Steel*. Smooth steel (welded) pipe can be utilized for drainage facilities under conditions where corrugated metal or concrete pipe will not meet the structural or design service life requirements.
- (2) *Composite Steel Spiral Rib Pipe*. Composite steel spiral rib pipe is a smooth interior pipe with efficient hydraulic characteristics. See Table 851.2.

Composite steel spiral rib pipe with its interior polyethylene liner exhibits good abrasion resistance and also resists corrosion from chemicals found in a typical stormdrain or sanitary sewer environment. The exterior of the pipe is protected with a polyethylene film which offers resistance to corrosive backfills. The pipe will meet a 50 year maintenance free service life under most conditions.

- (3) *Proprietary Pipe*. See Indexes 110.10 and 601.5(3) for further discussion and guidelines on the use of proprietary items.

854.6 Structural Metal Plate

- (1) *Pipe and Arches*. Structural plate pipes and arches are available in steel and aluminum for the diameters and thickness as shown on Tables 854.6A, B, C & D.

- (2) *Strength Requirements*.

- (a) Design Standards.

- **Corrugation Profiles** - Structural plate pipe and arches are available in a 6" x 2" corrugation for steel and a 9" x 2½" corrugation profile for aluminum.
- **Metal Thickness** - structural plate pipe and pipe arches are available in thickness as indicated on Tables 854.6A, B, C & D.
- **Height of Fill** - The allowable height of cover over structural plate pipe and pipe arches for the available diameters and thickness are shown on Tables 854.6A, B, C & D.

Where a maximum overflow is not listed on these tables, the pipe or arch size is not normally available in that thickness.

Table 854.3B
Corrugated Steel Pipe
Helical Corrugations

Diameter (in)	MAXIMUM HEIGHT OF COVER (ft)					
	Metal Thickness (in)					
	0.052 (18 ga.)	0.064 (16 ga.)	0.079 (14 ga.)	0.109 (12 ga.)	0.138 (10 ga.)	0.168 (8 ga.)
2$\frac{2}{3}$" x $\frac{1}{2}$" Corrugations						
12-15	99	99	--	--	--	--
18	89	99	--	--	--	--
21	77	96	99	--	--	--
24	67	84	99	--	--	--
30	53	67	84	99	--	--
36	44	56	70	98	99	--
42	38	48	60	84	99	--
48	--	42	52	79	94	99
54	--	--	46	65	84	92
60	--	--	--	59	75	92
66	--	--	--	--	69	84
72	--	--	--	--	63	77
78	--	--	--	--	--	68
84	--	--	--	--	--	59
3" x 1" Corrugations						
48	--	48	60	84	108	133
45	--	43	53	75	97	118
60	--	38	48	67	87	105
66	--	35	44	61	79	97
72	--	32	40	56	72	89
78	--	29	37	52	67	82
84	--	27	34	48	62	75
90	--	25	32	45	57	70
96	--	--	30	42	54	65
102	--	--	28	39	51	62
108	--	--	--	37	48	59
114	--	--	--	35	46	56
120	--	--	--	33	42	53

NOTE:

- (1) When flow velocity exceeds 5 ft/s under abrasive conditions, thicker metal may be required.

Table 854.3C
Corrugated Steel Pipe
Helical Corrugations

Diameter (in)	MAXIMUM HEIGHT OF COVER (ft)			
	Metal Thickness (in)			
	0.064 (16 ga.)	0.079 (14 ga.)	0.109 (12 ga.)	0.138 (10 ga.)
	5" x 1" Corrugations			
48	43	54	75	--
54	38	48	67	86
60	34	43	60	77
66	31	39	55	70
72	28	36	50	64
78	26	33	46	59
84	24	30	43	55
90	23	28	40	51
96	--	27	37	48
102	--	25	35	45
108	--	--	33	43
114	--	--	31	40
120	--	--	30	38

NOTE:

- (1) When flow velocity exceeds 5 ft/s under abrasive conditions, thicker metal may be required.

Table 854.3D
Corrugated Steel Pipe
2²/₃" x 1/2" Annular Corrugations

Diameter (in)	MAXIMUM HEIGHT OF COVER (ft)				
	Metal Thickness (in)				
	0.064 (16 ga.)	0.079 (14 ga.)	0.109 (12 ga.)	0.138 (10 ga.)	0.168 (8 ga.)
18	54	--	--	--	--
21	47	--	--	--	--
24	41	44	--	--	--
30	32	35	--	--	--
36	27	29	38	--	--
42	30	40	62	68	--
48	26	36	54	60	63
54	--	32	48	53	50
60	--	--	43	48	50
66	--	--	--	43	45
72	--	--	--	40	42
78	--	--	--	--	38
84	--	--	--	--	36

NOTE:

(1) When flow velocity exceeds 5 ft/s under abrasive conditions, thicker metal may be required.

Table 854.3E
Corrugated Steel Pipe Arches
2 $\frac{2}{3}$ " x $\frac{1}{2}$ " Helical or Annular Corrugations

Span-Rise (in)	Design Bearing (tons/ft ²)	Minimum Corner Radius (in)	MAXIMUM HEIGHT OF COVER (ft)			
			Metal Thickness (in)			
			0.079 (14 ga.)	0.109 (12 ga.)	0.138 (10 ga.)	0.168 (8 ga.)
21 x 15	2 $\frac{1}{2}$	3.0	10	--	--	--
24 x 18	2 $\frac{3}{4}$	3.0	10	--	--	--
28 x 20	3 $\frac{1}{4}$	3.0	10	--	--	--
35 x 24	4 $\frac{1}{4}$	3.0	10	--	--	--
42 x 29	4 $\frac{1}{4}$	3.5	10	--	--	--
49 x 33	4 $\frac{1}{4}$	4.0	10	--	--	--
57 x 38	4	5.0	--	10	--	--
64 x 43	3 $\frac{3}{4}$	6.0	--	10	--	--
71 x 47	3 $\frac{1}{2}$	7.0	--	--	10	--
77 x 52	3 $\frac{1}{2}$	8.0	--	--	--	10
83 x 57	3 $\frac{1}{4}$	9.0	--	--	--	10

NOTES:

- (1) When flow velocity exceeds 5 ft/s under abrasive conditions, thicker metal may be required.
- (2) Cover limited by corner soil bearing pressure as shown.

Table 854.3F
Steel Spiral Rib Pipe
 $\frac{3}{4}$ " x 1" Ribs at 11½" Pitch

Diameter (in)	MAXIMUM HEIGHT OF COVER (ft)		
	Metal Thickness (in)		
	0.064 (16 ga.)	0.079 (14 ga.)	0.109 (12 ga.)
24	40	57	96
30	32	45	76
36	27	38	64
42	23	32	54
48	20	28	48
54	18	25	42
60	16	22	38
66	--	20	34
72	--	19	32
78	--	--	29
84	--	--	27
90	--	--	25
96	--	--	24

NOTES:

- (1) When flow velocity exceeds 5 ft/s under abrasive conditions, thicker metal may be required.

Table 854.3G
Steel Spiral Rib Pipe
 $\frac{3}{4}$ " x 1" Ribs at 8½" Pitch

Diameter (in)	MAXIMUM HEIGHT OF COVER (ft)		
	Metal Thickness (in)		
	0.064 (16 ga.)	0.079 (14 ga.)	0.109 (12 ga.)
24	54	75	125
30	43	60	100
36	36	50	83
42	31	43	71
48	27	37	62
54	24	33	55
60	21	30	50
66	19	27	45
72	18	25	41
78	--	23	38
84	--	21	35
90	--	--	33
96	--	--	31
102	--	--	29
108	--	--	27
114	--	--	26

NOTES:

- (1) When flow velocity exceeds 5 ft/s under abrasive conditions, thicker metal may be required.

Table 854.3H
Steel Spiral Rib Pipe
 $\frac{3}{4}$ " x $\frac{3}{4}$ " Ribs at 7 $\frac{1}{2}$ " Pitch

Diameter (in)	MAXIMUM HEIGHT OF COVER (ft)		
	Metal Thickness (in)		
	0.064 (16 ga.)	0.079 (14 ga.)	0.109 (12 ga.)
24	55	77	128
30	44	62	103
36	36	51	85
42	31	44	73
48	27	38	64
54	24	34	57
60	--	31	51
66	--	28	46
72	--	--	42
78	--	--	39
84	--	--	36

NOTES:

- (1) When flow velocity exceeds 5 ft/s under abrasive conditions, thicker metal may be required.

Table 854.4A
Corrugated Aluminum Pipe
Annular Corrugations

Diameter (in)	MAXIMUM HEIGHT OF COVER (ft)				
	Metal Thickness (in)				
	0.060 (16 ga.)	0.075 (14 ga.)	0.105 (12 ga.)	0.135 (10 ga.)	0.164 (8 ga.)
2$\frac{2}{3}$" x $\frac{1}{2}$" Corrugations					
12	44	44	--	--	--
15	35	35	61	--	--
18	29	29	51	--	--
21	25	25	43	--	--
24	22	22	38	39	--
30	--	17	30	31	--
36	--	14	25	26	--
42	--	--	44	46	--
48	--	--	38	40	41
54	--	--	--	36	37
60	--	--	--	32	33
66	--	--	--	--	30
72	--	--	--	--	26
3" x 1" Corrugations					
30	32	40	55	82	--
36	27	33	45	68	89
42	23	28	39	59	76
48	20	25	34	51	66
54	18	22	30	45	59
60	16	20	27	41	53
66	14	18	25	37	48
72	13	16	22	34	44
78	--	15	21	31	41
84	--	--	19	29	38
90	--	--	18	27	35
96	--	--	17	25	33
102	--	--	--	24	31
108	--	--	--	22	29
114	--	--	--	--	26
120	--	--	--	--	23

NOTE:

(1) Not recommended under abrasive conditions.

Table 854.4B
Corrugated Aluminum Pipe
Helical Corrugations

Diameter (in)	MAXIMUM HEIGHT OF COVER (ft)				
	Metal Thickness (in)				
	0.060 (16 ga.)	0.075 (14 ga.)	0.105 (12 ga.)	0.135 (10 ga.)	0.164 (8 ga.)
2$\frac{2}{3}$" x $\frac{1}{2}$" Corrugations					
12	98	98	--	--	--
15	98	98	98	--	--
18	80	98	98	--	--
21	71	87	98	--	--
24	61	78	98	98	--
30	--	61	85	98	--
36	--	51	71	92	--
42	--	--	61	79	--
48	--	--	52	67	84
54	--	--	--	56	69
60	--	--	--	44	56
66	--	--	--	--	44
72	--	--	--	--	36
3" x 1" Corrugations					
30	53	70	98	99	--
36	46	59	82	99	99
42	40	50	70	94	99
48	35	44	61	82	97
54	31	39	54	73	86
60	28	35	49	66	77
66	25	32	44	60	70
72	23	29	41	55	64
78	--	27	38	50	59
84	--	--	35	47	55
90	--	--	32	44	51
96	--	--	30	40	48
102	--	--	--	36	43
108	--	--	--	33	39
114	--	--	--	--	35
120	--	--	--	--	31

NOTE:

(1) Not recommended under abrasive conditions.

Table 854.4C
Corrugated Aluminum Pipe Arches
2²/₃" x 1¹/₂" Helical or Annular Corrugations

Span-Rise (in)	Req'd Bearing (tons/ft ²)	Minimum Corner Radius (in)	MAXIMUM HEIGHT OF COVER (ft)				
			Metal Thickness (in)				
			0.060 (16 ga.)	0.075 (14 ga.)	0.105 (12 ga.)	0.135 (10 ga.)	0.164 (8 ga.)
17 x 13	2	3.0	10	--	--	--	--
21 x 15	2 ¹ / ₂	3.0	10	--	--	--	--
24 x 18	2 ³ / ₄	3.0	10	--	--	--	--
28 x 20	3 ¹ / ₄	3.0	10	--	--	--	--
35 x 24	4	3.0		10	--	--	--
42 x 29	4 ¹ / ₄	3.5	--	10	--	--	--
49 x 33	4 ¹ / ₂	4.0	--	--	10	--	--
57 x 38	4	5.0	--	--	--	10	--
64 x 43	3 ³ / ₄	6.0	--	--	--	10	--
72 x 47	3 ¹ / ₂	7.0	--	--	--	--	10

NOTES:

- (1) Cover is limited by corner soil bearing pressure as shown.
- (2) Not recommended under abrasive conditions.

Table 854.4D
Aluminum Spiral Rib Pipe
 $\frac{3}{4}$ " x 1" Ribs at 11½" Pitch

Diameter (in)	MAXIMUM HEIGHT OF COVER (ft)		
	Metal Thickness (in)		
	0.060 (16 ga.)	0.075 (14 ga.)	0.105 (12 ga.)
24	24	33	55
30	19	27	44
36	16	22	36
42	--	19	31
48	--	--	27
54	--	--	24
60	--	--	22
66	--	--	--
72	--	--	--

NOTES:

- (1) Not recommended under abrasive conditions.

Table 854.4E
Aluminum Spiral Rib Pipe
 $\frac{3}{4}$ " x $\frac{3}{4}$ " Ribs at 7 $\frac{1}{2}$ " Pitch

Diameter (in)	MAXIMUM HEIGHT OF COVER (ft)		
	Metal Thickness (in)		
	0.60 (16 ga.)	0.075 (14 ga.)	0.105 (12 ga.)
24	32	45	72
30	26	36	57
36	21	30	48
42	--	25	42
48	--	--	36
54	--	--	32
60	--	--	28
66	--	--	--
72	--	--	--

NOTES:

- (1) Not recommended under abrasive conditions.

Table 854.6A
Structural Steel Plate Pipe
6" x 2" Corrugations

Diameter (in)	MAXIMUM HEIGHT OF COVER (ft)					
	Metal Thickness (in)					
	0.109 (12 ga.)	0.138 (10 ga.)	0.168 (8 ga.)	0.218 (5 ga.)	0.249 (3 ga.)	0.280 (1 ga.)
60	55	81	105	137	159	178
66	50	74	96	125	145	162
72	46	68	88	114	133	149
77	42	62	81	106	122	137
84	39	58	76	99	113	127
90	36	54	71	92	105	119
96	35	51	66	87	99	112
102	32	48	62	81	93	105
108	30	45	59	77	88	99
114	29	43	56	73	83	94
120	27	40	53	69	79	89
126	26	38	50	66	75	85
132	25	37	48	63	72	81
138	24	35	46	60	69	77
144	23	34	44	58	66	74
150	22	32	42	55	63	71
156	21	31	40	53	61	68
162	20	30	39	51	58	66
168	19	29	38	49	56	64
174	19	28	36	48	54	61
180	18	27	35	46	52	59
186	17	26	34	44	51	57
192	--	25	33	43	49	56
198	--	24	32	42	48	54
204	--	24	31	40	46	52
210	--	23	30	39	45	51
216	--	--	29	38	44	49
222	--	--	28	37	42	48
228	--	--	28	36	41	47
234	--	--	27	35	40	45
240	--	--	--	34	39	44
246	--	--	--	33	38	43
252	--	--	--	33	37	42

NOTE:

(1) When flow velocities exceeds 5 ft/s under abrasive conditions thicker metal may be required.

Table 854.6B
Structural Steel Plate Pipe Arches
6" x 2" Corrugations

MAXIMUM HEIGHT OF COVER (ft)			
Span	Rise	Corner Soil Bearing – 3 tons/ft ²	
		Metal Thickness (in)	
		0.109 (12 ga.)	0.138 (10 ga.)
		18" Corner Radius	
6'-1"	4'-7"	21	--
7'-0"	5'-1"	18	--
7'-11"	5'-7"	16	--
8'-10"	6'-1"	14	--
9'-9"	6'-7"	13	--
10'-11"	7'-1"	11	--
31" Corner Radius			
13'-3"	9'-4"	16	--
14'-2"	9'-10"	15	--
15'-4"	10'-4"	14	--
16'-3"	10'-10"	13	--
17'-2"	11'-4"	12	--
18'-1"	11'-10"	11	--
19'-3"	12'-4"	11	--
19'-11"	12'-10"	--	10
20'-7"	13'-2"	--	10

NOTES:

- (1) For intermediate sizes, the depth of cover may be interpolated.
- (2) The 31-inch corner radius arch should be specified when conditions will permit it use.

Table 854.6C
Structural Aluminum Plate Pipe
9" x 2½" Corrugations

Diameter (in)	MAXIMUM HEIGHT OF COVER (ft)						
	Metal Thickness (in)						
	0.100	0.125	0.150	0.175	0.200	0.225	0.250
60	36	54	66	77	88	99	99
66	33	49	60	70	80	90	99
72	30	45	55	64	73	83	92
78	28	41	51	59	68	76	85
84	26	38	47	55	63	71	79
90	24	36	44	51	59	66	74
96	23	33	41	48	55	62	69
102	21	31	39	45	52	58	65
108	20	30	37	43	49	55	61
114	19	28	35	40	46	52	58
120	18	27	33	38	44	49	55
126	17	25	31	36	42	47	52
132	16	24	30	35	40	45	50
138	16	23	28	33	38	43	48
144	15	22	27	32	36	41	46
150	--	21	26	31	35	39	44
156	--	20	25	29	34	38	42
162	--	--	24	28	32	36	41
168	--	--	23	27	31	35	39
174	--	--	22	26	30	34	38
180	--	--	--	25	29	33	37
186	--	--	--	25	28	32	35
192	--	--	--	--	27	31	34
198	--	--	--	--	26	30	33
204	--	--	--	--	26	29	32
210	--	--	--	--	--	28	31
216	--	--	--	--	--	27	30
222	--	--	--	--	--	--	30
228	--	--	--	--	--	--	29

NOTE:

(1) Not recommended under abrasive conditions.

Table 854.6D
Structural Aluminum Plate Pipe Arches
9" x 2½" Corrugations

Span	Rise	MAXIMUM HEIGHT OF COVER (ft)					
		Corner Soil Bearing – 3 tons/ft ²					
		Metal Thickness (in)					
		0.100	0.125	0.150	0.175	0.200	0.225
6'-7"	5'-8"	28	--	--	--	--	--
7'-9"	6'-0"	23	--	--	--	--	--
8'-10"	6'-4"	20	--	--	--	--	--
9'-11"	6'-8"	18	--	--	--	--	--
10'-3"	6'-9"	16	21	--	--	--	--
11'-1"	7'-0"	16	20	20	--	--	--
12'-3"	7'-3"	15	18	18	--	--	--
12'-11"	7'-6"	14	17	17	--	--	--
13'-1"	8'-2"	14	17	17	--	--	--
13'-11"	8'-5"	12	16	16	--	--	--
14'-0"	8'-7"	12	15	16	--	--	--
14'-8"	9'-8"	--	15	15	--	--	--
15'-7"	10'-2"	--	14	14	--	--	--
16'-1"	10'-4"	--	13	13	--	--	--
16'-9"	10'-8"	--	--	13	--	--	--
17'-9"	11'-2"	--	--	--	12	--	--
18'-8"	11'-8"	--	--	--	11	--	--
19'-10"	12'-1"	--	--	--	--	10	--
20'-10"	12'-7"	--	--	--	--	--	10
21'-6"	12'-11"	--	--	--	--	--	10

NOTE:

(1) Not recommended under abrasive conditions.

(2) 31 inch Corner Radius

- (b) **Basic Premise.** To properly use the above mentioned tables, the designer should be aware of the premises on which the tables are based as well as their limitations. The design tables presuppose:
- That bedding and backfill satisfy the terms of the Standard Specifications, the conditions of cover, and pipe or arch size required by the plans and the essentials of Index 829.2.
 - That a small amount of settlement will occur under the culvert, equal in magnitude to that of the adjoining material outside the trench.
- (c) **Limitations.** In using the tables, the following restrictions should be kept in mind.
- The values given for each size of structural plate pipe or arch constitute the maximum height of overfill or cover over the pipe or arch for the thickness of metal and kind of corrugation.
 - The thickness shown is the structural minimum. For steel pipe or pipe arches, where abrasive conditions are anticipated, additional metal thickness or a paved invert should be provided when required to fulfill the design service life requirements. Table 854.3A may be used.
 - Where needed, adequate provisions for corrosion resistance must be made to achieve the required design service life called for in the references mentioned herein.
 - Tables 854.6B & D show the limit of heights of cover for structural plate arches based on the supporting soil sustaining a bearing pressure of 3 tons per square foot at the corners.
- (d) **Special Designs.** If the height of overfill exceeds the tabular values, or if the foundation investigation reveals that the supporting soil will not develop the bearing pressure on which the overfill heights for structural plate pipe or pipe arches are based, a special design prepared by the Division of Structures is required.
- Asphalt mastic (if there are no environmental concerns) is an acceptable field applied alternative for bituminous coating for non-abrasive flow conditions on the inside of the culvert. Under these circumstances, a special provision will be required to specify this alternative.
- (3) **Arches.** Design details with maximum allowable overfills for structural plate arches, with cast in place concrete footings may be obtained from the Division of Structures.
- (4) **Vehicular Underpasses.** Design details with maximum allowable overfills for structural plate vehicular underpasses with spans from 12 feet 2 inches to 20 feet 4 inches, inclusive, are given in the Standard Plans. These designs are based on bearing soil pressures from 1.4 tons per square foot to 5.8 tons per square foot.
- (5) **Special Shapes.**
- (a) **Long Span. (Text Later)**
 - Arch
 - Low Profile Arch
 - High Profile Arch
 - (b) **Ellipse. (Text Later)**
 - Vertical
 - Horizontal
 - (c) **Inverted Box. (Text Later)**
 - (d) **Box. (Text Later)**
- (6) **Tunnel Liner Plate.**
- The Division of Structures will prepare designs upon request.
- ### 854.7 Concrete Box and Arch Culverts
- (1) **Box Culverts.** Single and multiple span reinforced concrete box culverts are completely detailed in the Standard Plans. For cast-in-place construction, strength classifications are shown for 10 feet and 20 feet overfills.

Standard Detail Sheets are available for precast reinforced concrete box culverts. They may be obtained electronically, from the District Hydraulics Engineer or by contacting the Division of Structures. Precast reinforced concrete box culverts require a minimum of 1 foot of overfill and are not to exceed 12 feet in span length. Special details are necessary if precast boxes are proposed as extensions for existing box culverts. Where the use of precast box culverts is applicable, the project plans should include them as an alternative to cast-in-place construction. Because the standard measurement and payment clauses for precast RCB's differ from cast-in-place construction, precast units must be identified as an alternative on the standard detail sheets and the special provision must be appropriately modified.

The standard detail sheets for precast boxes show details which require them to be laid out with joints perpendicular to the centerline of the box. This is a consideration for the design engineer in situations which require stage construction and when the culvert is to be aligned on a high skew. This situation will require either a longer culvert than otherwise may have been needed, or a special design allowing for skewed joints. Prior to selecting the latter option the Division of Structures should be consulted.

- (2) *Concrete Arch Culverts.* Design details for concrete arch culverts in 1 foot span increments from 6 feet to 22 feet, inclusive, allowing a maximum overfill height up to 60 feet, are given in the Standard Plans. These designs are based on footing soil pressures ranging from 2.4 tons per square foot to 7.5 tons per square foot.
- (3) *Corrosion, Abrasion, and Invert Protection.* Refer to Topics 854.1(1), (2), and (4) for corrosion, abrasion and invert protection of concrete box and arch culverts.

854.8 Plastic Pipe

- (1) *Durability.* The durability of plastic pipe is determined by the long term performance of its material properties. Plastic pipe culverts exhibit good abrasion resistance and are virtually corrosion free, permitting a 50 year maintenance free service life under most conditions. Long term exposure to direct sunlight can lead to brittleness

in polyvinyl chloride (PVC) pipes, and such situations should be avoided. Plastic pipe culverts are chemically inert under typical soil conditions.

In areas with high fire potential, use limitations or modifications of plastic pipe should be considered. Application limitations may include down drains and projecting ends of cross drains in densely vegetated or grassy locations. The projecting ends of plastic pipe cross drains can be replaced with corrugated metal pipe, concrete pipe, concrete headwalls or wingwalls, or other modifications, thereby reducing the potential of fire damage. The connection between the plastic pipe and the modified end piece would be nonstandard.

(2) *Strength Requirements.*

(a) Design Standards

- **Materials** - Plastic pipe shall be either Type C (corrugated exterior and interior) corrugated polyethylene pipe, Type S (corrugated exterior and smooth interior) corrugated polyethylene pipe, profile wall polyethylene pipe, profile wall polyvinyl chloride pipe, or ribbed polyvinyl chloride pipe.
- **Height of Fill** - The allowable overfill heights for plastic pipe for various diameters are shown in Table 854.8.

- (b) **Basic Premise.** To properly use the plastic pipe height of fill table, the designer should be aware of the basic premises on which the table are based as well as their limitations. The design table presupposes:

- That bedding and backfill satisfy the terms of the Standard Specifications, the conditions of cover, and pipe size required by the plans and the essentials of Index 829.2.
- That a small amount of settlement will occur under the culvert, equal in magnitude to that of the adjoining material outside the trench.

854.9 Minimum Height of Cover

Table 854.9 gives the minimum thickness of cover required for design purposes over pipes and pipe arches. For construction purposes, a minimum cover of 6 inches greater than the roadway structural section is desirable for all types of pipe.

Class 4 concrete backfill may be used for culverts when it is necessary to have less than 2 feet of cover below the top of a flexible pavement, except that minor concrete backfill must not be placed against aluminum or aluminized culverts. A minimum of 6 inches of concrete backfill should be used at the sides of a culvert.

Table 854.8
Thermoplastic Pipe Fill Height
Tables

High Density Polyethylene (HDPE)
Corrugated Pipe

Size (in)	Maximum Height of Cover (ft)
12	30
15	30
18	30
24	30
30	30
36	30
42	20
48	20

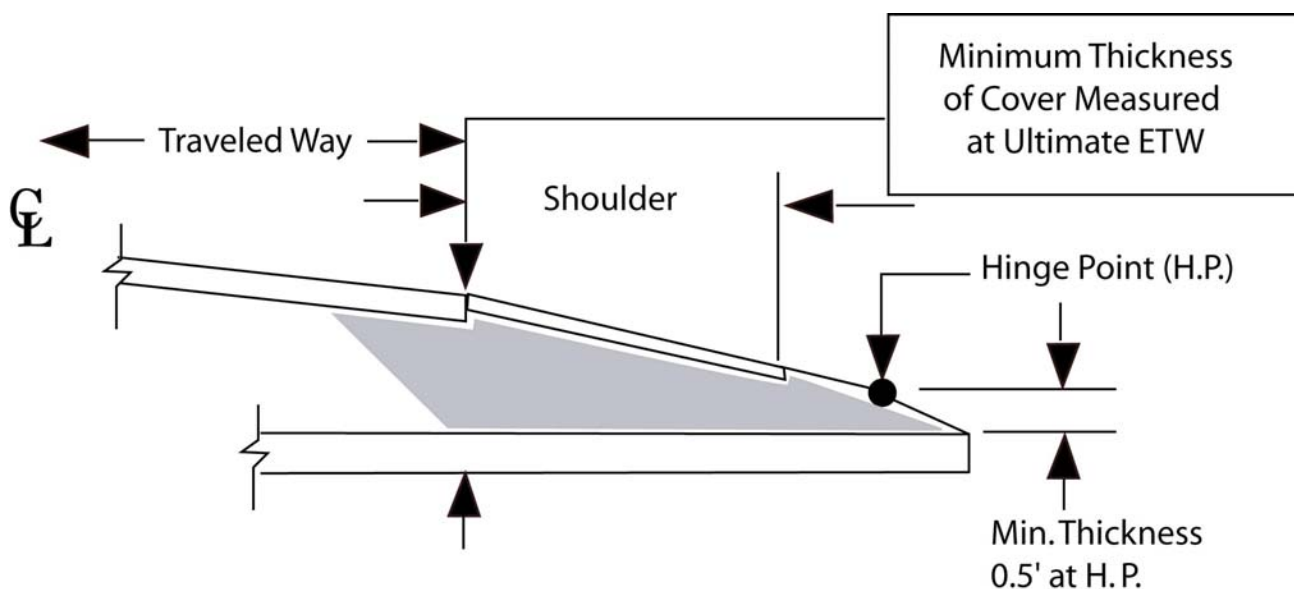
High Density Polyethylene (HDPE)
Ribbed Pipe

Size (in)	Maximum Height of Cover (ft)
18	24
21	24
24	24

Polyvinyl Chloride (PVC) Ribbed Pipe

Size (in)	Maximum Height of Cover (ft)
18	27
21	26
24	25
27	24
30	23
36	22
42	21
48	20

Table 854.9
Minimum Thickness of Cover
for Culverts



MINIMUM THICKNESS OF COVER AT ETW

SURFACE TYPE	Corrugated metal pipes and pipe-arches	Structural plate pipes and pipe-arches	Reinforced concrete pipes	Plastic pipes	Cast-In-Place concrete pipes
Flexible Pavements or Unpaved	1/5 (dia. or span) or 2 ft. minimum.	1/8 (dia. or span) or 2 ft. minimum	2 ft. minimum	2 ft. minimum	Structural Section plus 2 ft.
Rigid Pavements	1/5 (dia. or span) or 1.2 ft. minimum.	1/8 (dia. or span) or 1.2 ft. minimum	1 ft. minimum	2 ft. minimum	Structural Section plus 2 ft.

Note: See Index 854.2(1)(d) for necessary approvals prior to placing cast-in-place concrete pipes under the roadway.